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Differential emotional processing in concrete and abstract words

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Running head: Concrete and abstract emotion

Abstract

Emotion (positive and negative) words are typically recognized faster than neutral words. Recent research suggests that emotional valence, while often treated as a unitary semantic property, may be differentially represented in concrete and abstract words. Studies that have explicitly examined the interaction of emotion and concreteness, however, have demonstrated inconsistent patterns of results. Moreover, these findings may be limited as certain key lexical variables (e.g., familiarity, age of acquisition) were not taken into account. We investigated the emotion-concreteness interaction in a large-scale, highly-controlled lexical decision experiment. A 3 (Emotion: negative, neutral, positive) × 2 (Concreteness: abstract, concrete) design was used, with 45 items per condition and 127 participants. We found a significant interaction between emotion and concreteness. Although positive and negative valenced words were recognized faster than neutral words, this emotion advantage was significantly larger in concrete than in abstract words. We explored potential contributions of participant alexithymia level and item imageability to this interactive pattern. We found that only word imageability significantly modulated the emotion-concreteness interaction. While both concrete and abstract emotion words are advantageously processed relative to comparable neutral words, the mechanisms of this facilitation are paradoxically more dependent on imageability in abstract words.

Keywords: emotion, concrete, abstract, word recognition, lexical decision, grounded cognition, alexithymia, imageability

A great deal of recent psycholinguistic research has demonstrated that emotionally valenced (positive and negative) written words (e.g., *trophy*, *poison*) are generally recognized faster than neutral words (e.g., *basket*) (Kanske & Kotz, 2007; Knickerbocker, Johnson, & Altarriba, 2015; Kousta, Vinson, & Vigliocco, 2009; Kuchinke, Võ, Hofmann, & Jacobs, 2007; Kuperman, Estes, Brysbaert, & Warriner, 2014; Larsen, Mercer, & Balota, 2006; Méndez-Bértolo, Pozo, & Hinojosa, 2011; Nakic, Smith, Busis, Vythilingam, & Blair, 2006; Schacht & Sommer, 2009; Scott, O'Donnell, Leuthold, & Sereno, 2009; Scott, O'Donnell, & Sereno, 2012, 2014; Sereno, Scott, Yao, Thaden, & O'Donnell, 2015; Sheikh & Titone, 2013). However, the underlying basis for this valence advantage remains less certain. Some researchers propose that the valence effect is attentional in nature, activated during earlier stages of lexical processing. That is, valenced words may capture extra attention either because they activate appetitive-aversive motivational systems (Lang, Bradley, & Cuthbert, 1990, 1997) or because of their particular relevance to survival (Estes & Adelman, 2008; Kuperman et al., 2014; Pratto & John, 1991; Scott et al., 2009; Taylor, 1991). Other researchers suggest that the valence effect may reflect activations of emotional experiences and is anchored in a word's semantics (Barsalou & Wiemer-Hastings, 2005; Kousta, Vigliocco, Vinson, Andrews, & Del Campo, 2011).

Although often treated as a unitary semantic property, emotional valence may be differentially represented in concrete and abstract words. Concrete words (e.g., *path*, *mirror*) refer to physical entities in time and space. Abstract words (e.g., *duty*, *aspect*) are more representative of concepts or ideas. Grounded cognition theories propose that concrete words are primarily represented in sensorimotor experiences of the physical world (Barsalou, 1999, 2008), while abstract words rely more on situational events and introspective information such as emotions (Barsalou & Wiemer-Hastings, 2005). In the literature, two alternative views have been developed that differentially account for the role of emotional valence in the lexical processing of concrete versus abstract words. We will refer to these as the “representational substitution” and “multimodal induction” hypotheses.

The “representational substitution” hypothesis argues that emotions play a more central role in representing abstract words, and predicts a larger valence effect in lexical processing of abstract words than in concrete words. Kousta et al. (2011) proposed that abstract words tend to be more emotionally valenced than concrete words, giving rise to a residual processing advantage of abstract over concrete words, critically, once differences in context availability and imageability are taken into account. Using functional magnetic imaging (fMRI), Vigliocco et al. (2014) observed greater activation of the rostral anterior cingulate cortex (rACC; an area associated with emotional processing) during the visual recognition of abstract compared to concrete words. These findings suggest that abstract words may be primarily represented in emotional experiences in replacement of or substitution for sensorimotor experiences. Consequently, emotional valence should contribute more fundamentally to the lexical processing of abstract than concrete words. Importantly, the valence effect in abstract words should be modulated by individuals’ abilities to activate emotional feelings. For example, alexithymia is a normally-distributed personality construct defined by difficulties in identifying and describing emotions, an impoverished fantasy life, and externally-oriented thinking (Sifneos, 1973; Taylor, Bagby, & Parker, 1997). Accordingly, people with high levels of alexithymia may display impairment in recognizing abstract words specifically.

In contrast, the “multimodal induction” hypothesis favors a valence advantage for concrete relative to abstract words. It argues that emotions may be more accessible for concrete words, as emotions can be readily evoked or induced via the activation of relevant sensorimotor experiences. Grounded cognition theories predict that the conceptual representations of emotions are inherently multimodal. Perceiving an emotional stimulus (e.g., a smiling face, the word "smile"), simulating emotionally-relevant bodily states (e.g., activating one's own smiling muscles), and experiencing an emotion (e.g., feeling happy) all would engage highly interconnected sensory, motor, and affective systems (Niedenthal, 2007). For example, it has been shown that perceiving dynamic facial expressions can influence one's own emotional states (Hess & Blairy, 2001); conversely, lesions to right somatosensory-related cortices are associated with impairments in recognizing emotional facial expressions (Adolphs, Damasio, Tranel, Cooper, & Damasio, 2000). Partial activation of this processing circuit (e.g., seeing a smiling face, reading the word "smile") may cascade to complementary activations in other components of the circuit (e.g., feeling happy). In other words, seeing a smiley face would facilitate feeling happy. Thus, the emotional valence effect may be more pronounced during the lexical processing of concrete than abstract words, given the former's stronger associations with sensorimotor information. This hypothesis also predicts that, regardless of concreteness, words with higher imageability (i.e., ease of eliciting a mental image; e.g., Balota, Cortese, Sergent-Marshall, Spieler, & Yap, 2004) – a measure which at least partially captures a word's associations with sensorimotor information – may display stronger valence effects.

To our knowledge, three studies have explicitly examined the interaction between emotional valence and concreteness in visual word processing. Kanske and Kotz (2007) used lateralized presentation of concrete and abstract German nouns of positive, negative, and neutral valence in two lexical decision tasks and recorded reaction times (RTs) and event-related potentials (ERPs). Positive and negative valenced nouns were also higher in arousal than neutral nouns (3.20 and 3.49 vs. 1.53 on a 5-point scale, respectively). The first experiment used both word and nonword responses while their second experiment used a no-go/go (word/nonword) paradigm. Their RT data (Experiment 1) demonstrated advantages for concrete over abstract words as well as for positive and negative over neutral words (and for right over left visual field presentation). Although RTs to positive words were also faster than those to negative words, the emotion-concreteness interaction revealed that this difference was only reliable for concrete items. Kanske and Kotz (2007) also examined ERP effects in the P2 (210-300 ms), N400 (390-590 ms), and late positive component (LPC; 590-750 ms). They observed emotion effects in all three components (P2 effects were limited to Experiment 1). Concreteness effects, in contrast, appeared later, with concrete words eliciting greater negativity than abstract words in the N400 and LPC. Emotion and concreteness interacted in the LPC (only in Experiment 2), with emotion effects limited to concrete words (greater amplitudes to concrete negative compared to either concrete positive or neutral words). As the LPC has been linked to mental imagery (e.g., West & Holcomb, 2000), the authors suggested that negative concrete words in particular may provoke imagery of emotions, albeit peripheral to lexical access due to its late time signature.

Using ERPs and a lexical decision task, Palazova, Sommer, and Schacht (2013) revisited the interaction of emotion and concreteness with German verbs. Although their positive, negative, and neutral words all differed significantly from each other in arousal (2.9, 3.3, and 2.7 on a 5-point scale, respectively), the range in values was much reduced in comparison to that employed in Kanske and Kotz (2007). Behaviorally, Palazova et al. (2013) found RTs were *slower* to valenced (positive and negative) abstract relative to neutral verbs; there was no valence effect in concrete verbs. They suggested this ‘reverse’ emotion effect may be due to their use of verbs as targets which require greater semantic processing compared to other grammatical classes of words typically employed in emotion studies. Palazova et al. (2013) analyzed ERPs in consecutive, non-overlapping 50 ms time windows from stimulus onset in order to assess the differential timing of effects. The main effect of emotion (positive and negative vs. neutral) began at 250 ms, preceding the main effect of concreteness which began at 500 ms. However, a significant emotion-concreteness interaction occurred in both earlier (250-300 ms) and later (400-450 ms) time windows. The earlier window demonstrated a pattern opposite to that found with RTs, with valence effects (positive and negative vs. neutral) present only in concrete but not in abstract verbs; the later window showed valence effects for both verb types. They suggested that, in line with other studies (e.g., Kissler, Herbert, Peyk, & Junghofer, 2007; Schacht & Sommer, 2009), the earlier effects reflected lexico-semantic processing.

Sheikh and Titone (2013) examined eye movement measures on target words during sentence reading. Targets varied categorically in word frequency (high and low) and emotionality (positive, negative, and neutral valence), but continuously in concreteness. Although positive and negative words were significantly higher in arousal than neutral words (5.48 and 5.19 vs. 4.45, on a 9-point scale, respectively), like Palazova et al. (2013), the numerical difference was relatively small. In gaze duration (the sum of all consecutive fixations on a word before leaving it), using linear mixed-effects models (LMMs), they found shorter fixation times on valenced (positive and negative) relative to neutral words, but only for low frequency, abstract words. A gaze duration advantage was also found for concrete versus abstract words, but only for low frequency, neutral words. As effects were restricted to low frequency words (cf. Scott et al., 2012), the authors argued that the weaker representations of low frequency words necessitated stronger semantic contributions for recognition, whereas high frequency words could be sufficiently recognized without such involvement. Sheikh and Titone (2013) additionally examined whether participants' alexithymia level affected target word processing. They found that, in gaze duration, higher levels of alexithymia attenuated the benefit for positive relative to neutral words.

Although all three prior studies demonstrated an emotion-concreteness interaction, the pattern and nature of this interaction varied substantially. Some studies demonstrated valence effects only in abstract words (i.e., the 'reverse' pattern of RTs in Palazova et al., 2013; low frequency word gaze durations in Sheikh & Titone, 2013), supporting the "representational substitution" hypothesis. Others reported valence effects in concrete but not in abstract words (RT and ERP results in Kanske & Kotz, 2007; ERP results in Palazova et al., 2013), favoring the "multimodal induction" hypothesis. These discrepancies may be attributed to differences in grammatical class of the target words (nouns, verbs), task demands (lateralized presentation, no-go/go lexical decision, lexical decision, sentence reading), the measures used (RTs, ERPs, fixation times), and the language tested (German, English). Although all studies controlled for the stimulus variables of concreteness, valence, and word frequency, arousal values varied across studies. Differences in arousal between emotion (positive, negative) and neutral words was greater in Kanske and Kotz (2007) than in the other two studies. Other lexical variables that may have influenced the results but were not accounted for by any of the above studies are familiarity and age of acquisition (AoA), which may account for the asymmetry between positive and negative words (e.g., Kousta et al., 2009). Although familiarity is related to word frequency, it is a subjective measure and is considered a separate construct (e.g., Balota et al., 2004; Balota, Pilotti, & Cortese, 2001). AoA refers to the estimated age at which a word is learned. Words that are familiar or acquired earlier in life demonstrate a processing advantage to those that are unfamiliar or acquired later, respectively (e.g., Brown & Watson, 1987; Johnston & Barry, 2006; Juhasz & Rayner, 2003, 2006; Sereno & O'Donnell, 2009; Williams & Morris, 2004). Moreover, as imageability effects have been shown to be stronger in later-acquired words (Cortese & Schock, 2013), it is important to control for the influence of AoA when assessing effects of imageability.

The present study investigated the effects of emotion and concreteness in a large-scale, rigorously controlled lexical decision experiment. We implemented an Emotion (Negative, Neutral, Positive) × Concreteness (Abstract, Concrete) design. We used a total of 270 words (vs. 240, 108, and 156 words in the three previous studies, respectively) that were matched on an item-by-item basis for length and word frequency. We additionally controlled for the key lexical variables of arousal, familiarity, and AoA by including them as covariates in our analyses. Crucially, to test the nature of the Emotion × Concreteness interaction, we examined how individual variations in alexithymia level (predicted by the "representational substitution" hypothesis) and word imageability levels (predicted by the "multimodal induction" hypothesis) may have contributed to this interaction, using a much larger sample (127 participants) than the previous studies (30 and 18 participants in the experiments of Kanske & Kotz (2007); 42 and 43 participants in Palazova et al. (2013) and Sheikh & Titone (2013), respectively).

We predicted that emotionally valenced words would be recognized faster than neutral words. If the "representational substitution" hypothesis is correct, this valence effect would be stronger in abstract relative to concrete words. Moreover, the valence effects in abstract words would be negatively correlated with individual variations in alexithymia, with the emotion-concreteness interaction attenuated at higher alexithymia levels. In contrast, the "multimodal induction" hypothesis predicted that the valence advantage would be stronger in concrete as opposed to abstract words. In addition, the emotion-concreteness interaction would be at least partially accounted for by higher levels of imageability in concrete compared to abstract words.

Method

Participants

A total of 127 participants were included in the analyses (82 female; mean age 22.4 years, *SD*=4.8, range 18-44). All were native English speakers, right-handed, had normal or corrected-to-normal vision, had never been diagnosed with any reading disorder or psychiatric condition, and were either paid at a rate of £6/hr or given course credit for their participation. An additional five participants were run but their data were excluded because the number of RT trials rejected (based on errors and outliers combined) was more than 2 *SD*s from the group mean. The experimental procedure was approved by the College of Science and Engineering Ethics Committee at the University of Glasgow and participants gave written informed consent prior to testing.

Apparatus

The experiment was run on a Dual-core Dell PC, using the Matlab Psychophysics Toolbox (Version 3.0.12). Stimuli were presented on a 19” monitor (60 Hz, 1024 × 768 resolution) in a 25-point Consolas font (black letters on a light grey background). Participants sat at a viewing distance of approximately 60 cm. Responses were made on a PC keyboard and RTs were recorded with millisecond accuracy.

Design and Materials

We employed a 3 Emotion (Negative, Neutral, Positive) × 2 Concreteness (Abstract, Concrete) within-participants design. Our goal was to assemble a substantial set of stimuli that differed on the dimensions of interest but were, at the same time, controlled as best as possible across other key lexical variables. For example, although a large range of word lengths and frequencies were sampled over the materials as a whole, we were able to select sets of six words (from the crossing of Emotion and Concreteness) that were well matched on word length and frequency. Other lexical variables, however, were more difficult to match across conditions. For example, AoA is negatively correlated with concreteness, with earlier-acquired words tending to be more concrete (e.g., *zebra*) and later ones more abstract (e.g., *dogma*). For such variables, we included them as covariates in our analyses.

The experiment comprised 270 words ranging from 3 to 11 characters in length, with 45 items in each of the six conditions. Half of the words had relatively concrete meanings (e.g., *smile*) and half had relatively abstract meanings (e.g., *trust*). Within each Concreteness condition, one-third of the words were negatively valenced (e.g., *poison*, *scared*), one-third were emotionally neutral (e.g., *basket*, *custom*), and one-third were positively valenced (e.g., *trophy*, *worthy*).

Across all six conditions, words were matched on an item-by-item basis for word length (number of letters) and word frequency (occurrences per million). These item matches were exact for word length and highly similar for word frequency. An Emotion × Concreteness analysis of variance (ANOVA) performed on word frequencies by item revealed no statistical differences [all Fs<1]. Word frequencies were obtained from the British National Corpus (BNC), a database of 90 million written word tokens (http://www.natcorp.ox.ac.uk; Davies, 2004). All word stimuli are listed in **Appendix A**. Nonwords comprised 270 pronounceable, orthographically legal pseudowords (e.g., *famper*, *temice*) that were matched to word stimuli in terms of string length.

Ratings based on Likert scales for the lexical variables of valence (having a positive, neutral, or negative value), concreteness (having a physical form or not), arousal (calming or exciting), familiarity (unfamiliar or familiar), AoA (estimated age at which a word was learned), and imageability (ease or difficulty to imagine or picture) were obtained from our local database at the University of Glasgow (Scott, Keitel, Becirspahic, O'Donnell, & Sereno, *in prep*). The mean ratings of these variables (with *SDs*) across conditions are reported in **Table 1**.

Insert **Table 1** about here

Alexithymia levels of participants were assessed via the 20-item Toronto Alexithymia Scale (TAS-20; Bagby, Parker, & Taylor, 1994), with their total alexithymia score used in our analyses [Cronbach's α=.85].

Procedure

Participants were tested individually or as a group in a behavioral lab with PC workstations separated by privacy panels (maximum capacity 6), and the experiment (lexical decision task and TAS questionnaire) lasted just under an hour. For the lexical decision task, participants were informed that half of the stimuli were words and half were nonwords and their task was to press the corresponding button on the keyboard as quickly and as accurately as possible. They were first presented with a practice block of 12 trials to become accustomed to the task. Each trial began with a 500 ms blank screen followed by a small, green fixation circle displayed for 1500 ms at the center of the screen. The fixation circle was then replaced by the letter string until a response or 2000 ms had elapsed. Participants used their right and left forefingers on the two CTRL keys of the keyboard for responses. The key mapping for word and nonword responses was counterbalanced across participants. A response (or time out) automatically triggered the next trial. The 540 experimental trials were presented in a pseudo-random order in five blocks (108 trials per block). Each block contained equal numbers of words and nonwords with no more than three trials of the same condition presented consecutively. Trials were presented in a different order to each participant. The TAS-20 questionnaire was administered after the lexical decision task.

Results

For analyses of the RT data, error trials and trials where no response was given were initially removed (3.1% of word trials). The remaining RT data was subjected to two trimming procedures (with an additional data loss of 4.9%). First, trials with RTs less than 250 ms or greater than 1500 ms were excluded from further analyses. Second, for each participant in each condition, trials with RTs beyond two standard deviations were additionally excluded. These procedures (error and outlier removal) resulted in an average RT data loss of 8% per participant. The mean RT and %Error data across Emotion and Concreteness conditions are presented in **Table 2**.

Insert **Table 2** about here

Our focus is on RT as it represents the preponderance of the data. Although we present mean error percentages, we do not report analyses of these data (such analyses demonstrated a similar pattern of effects to that of the RT data). We fit three different models of RTs to test the interactions between the following: Emotion and Concreteness; Emotion, Concreteness, and Alexithymia; and Emotion, Concreteness, and Imageability. We also included log frequency, emotional arousal, familiarity, and AoA as control variables in all models. In LMMs, we used maximal random-effect structures as justified by the design (Barr, Levy, Scheepers, & Tily, 2013). If not stated otherwise, continuous predictors were used and were standardized before interaction terms were created.

Emotion × Concreteness

We fit an LMM of RTs using the *lmer* function in the lme4 package (version 1.1-10; Bates, Mächler, Bolker, & Walker, 2015) in R (www.r-project.org). We specified Emotion (i.e., absolute valence), Concreteness, their interaction, as well as log frequency, arousal, familiarity, and AoA in the fixed-effect structure to model word-level (by-item) variation. To model by-subject variation, we maximized the random-effect structure by including by-subject random intercept and slopes for all fixed effects. We report the estimated coefficient (*b*), standard error (SE), and *t*- and *p*-values in **Table 3**. The *p*-values were estimated using Satterthwaite approximations to degrees of freedom (lmerTest package; CRAN.R-project.org/package=lmerTest) and the figures were created using the interplot package (Solt & Hu, 2015). We also calculated the Variance Inflation Factors (VIFs) and all predictors had VIFs below 1.46 (Kutner, Nachtsheim, & Neter, 2004, recommend that VIFs>10 indicate high multicollinearity).

Insert **Table 3** about here

The effects of covariates were all significant (**Table 3**): log frequency, arousal, and familiarity negatively predicted RTs, while AoA positively predicted RTs. The main effects of Emotion and Concreteness were both significant and negatively predicted RTs (**Table 3**), demonstrating that emotional (positive and negative) words were recognized faster than neutral words, and that concrete words were recognized faster than abstract words, respectively. There was also a significant Emotion × Concreteness interaction (**Table 3**) and this is depicted in **Figure 1**. Exploring the interaction, we found that the Emotion effect was significantly stronger at higher levels of Concreteness [(M+SD); b=-8.0, 95% CI [-10.2 -5.8]] than at lower levels of Concreteness [(M-SD); b=-4.5, 95% CI [-6.5 -2.4]].

Insert **Figure 1** about here

This pattern of results is in line with the “multimodal induction” hypothesis, suggesting that emotional representations may be more accessible in concrete than in abstract words. It is incompatible with the “representational substitution” hypothesis, which predicts a stronger Emotion effect in abstract words. It could be argued, however, that the Emotion effect in abstract words may be selectively weakened due to the presence of participants with high levels of alexithymia. To test this conjecture, we investigated the relative contributions of Alexithymia to the Emotion × Concreteness interaction.

Emotion × Concreteness × Alexithymia

We fit a linear multiple regression model of RTs. The model included Emotion, Concreteness, Alexithymia, their interaction terms, as well as log frequency, arousal, familiarity and AoA. All VIFs were below 2.68, indicating relatively low collinearity among the predictors. Alexithymia levels were quantified by TAS scores that were collected in the TAS-20 questionnaire. TAS scores can range from 20-100; our sample ranged from 22-74 (M=46, SD=11), indicating that most levels of alexithymia were represented. This profile was comparable to that in Sheikh and Titone (2013) whose participants’ scores ranged from 28-75 (M=43, SD=11). The results are summarized in **Table 4**.

Insert **Table 4** about here

Similar to our basic model, all covariate effects were significant (**Table 4**). In addition, the main effects of Emotion and Concreteness, as well as their interaction also remained significant (**Table 4**). The pattern of the Emotion × Concreteness interaction was also similar. The Emotion effect was significantly stronger at higher (M+SD) than lower (M-SD) levels of Concreteness [b=-8.0, 95% CI [-10.3 -5.6] vs. b=-4.5, 95% CI [-6.7 -2.5], respectively].

There was a significant positive main effect of Alexithymia (**Table 4**), indicating that participants with high TAS scores responded more slowly overall as compared to participants with low TAS scores. However, Alexithymia did not interact with Emotion or Concreteness, separately or in combination. These results indicated that the Emotion × Concreteness interaction was not dependent on individual variations in alexithymia level, and, hence, did not provide support for the “representational substitution” hypothesis.

In contrast, the “multimodal induction” hypothesis predicts that activation of sensorimotor experiences facilitates emotional activation. The more pronounced valence effects in concrete words can be explained by their rich associations with sensorimotor information. Word imageability captures, at least partially, the extent to which a word is semantically associated with such sensorimotor information. Regardless of concreteness, the valence effects should be stronger in words with relatively higher levels of imageability.

Emotion × Concreteness × Imageability

We fit an initial LMM of RTs with Emotion, Concreteness, Imageability and their interactions, as well as log frequency, arousal, familiarity, and AoA in the fixed-effect structure. The random-effect structure included by-subject random intercept and slopes for all fixed effects. There were high correlations between Concreteness and Imageability (r=.93, VIFs=8.26 and 8.15), as well as between Emotion × Concreteness and Emotion × Imageability (r=.92, VIFs=7.39 and 7.52). Because this model’s focus was on the effects of imageability, we reduced the model by removing Concreteness and Emotion × Concreteness (i.e., the predictors with high VIFs) from the fixed-effect structure. The reduced model had relatively low multicollinearity, with VIFs<2.99. The results are summarized in **Table 5**. All covariates were significant (**Table 5**). The main effects of Emotion and Imageability were significant (**Table 5**), indicating that emotional words and high imageability words were recognized faster than neutral words and low imageability words, respectively. The Concreteness × Imageability interaction was also significant (**Table 5**). Exploring the interaction, we found that the imageability effect was significantly larger in Concrete (*M*+*SD*) than in Abstract (*M*-*SD*) words [*b*=-7.5, 95% CI [-10.2 -4.9] vs. *b*=-1.7, 95% CI [-4.1 0.7], respectively]. Importantly, there was an Emotion × Imageability interaction (**Table 5**), with the Emotion effect significantly stronger in high imageability words [*M*+*SD*; *b*=-13.6, 95% CI [-16.2 -11.1]] than in low imageability words [*M*-*SD*; *b*=-10.6, 95% CI [-13.4 -7.7]]. This supports the "multimodal induction" prediction that, regardless of concreteness, higher imageability levels (i.e., richer associations with sensorimotor information) should enhance valence effects.

Insert **Table 5** about here

The three-way interaction between Emotion, Concreteness, and Imageability was also significant (**Table 5**). This may reflect a stronger Emotion × Imageability interaction in concrete words due to their richer associations with sensorimotor information. To explore this interaction, we fit two separate LMMs on Concrete and Abstract words. In both LMMs, we included Emotion, Imageability, their interaction, as well as log frequency, arousal, familiarity, and AoA in the fixed-effect structure. For the random-effect structure, we specified by-subject random intercepts and slopes for all fixed effects. The VIFs were <1.71 in the Concrete LMM and were <1.65 in the Abstract LMM, indicating low levels of collinearity. The results are summarized in **Table 6**.

Insert **Table 6** about here

Paradoxically, the Emotion × Imageability interaction was in fact significant only in Abstract and not Concrete words (**Table 6**). These effects are depicted in **Figure 2**. Exploring the pattern of the interaction, we found that the Emotion effect in Abstract words (**Figure 2**, left panel) was significant at relatively higher levels of Imageability [(*M*+*SD*); *b*=-10.8, CI [-13.7 -7.8]], but not at lower levels of Imageability [(*M*-*SD*); *b*=-1.6, CI=[-4.4 1.2]]. In comparison, the Emotion effect in Concrete words (**Figure 2**, right panel) did not depend on Imageability level.

Insert **Figure 2** about here

The significant three-way interaction suggests that the Emotion × Concreteness interaction we observed in the basic model was driven, at least partially, by word imageability. However, the Emotion effect in concrete words was not actually enhanced by higher levels of imageability, as predicted by the "multimodal induction" hypothesis. Instead, the Emotion effect was reduced in abstract words due to the presence of "ultralow" imageability abstract words. Specifically, the Emotion effect was significant in higher- but not in "ultralow"-imageability abstract words. This Emotion × Imageability interaction supports the "multimodal induction" hypothesis, suggesting that emotional activation in abstract words may be facilitated by co-activation of relevant sensorimotor information. For instance, recognition of *cute* may benefit from activation of associated sensory information (e.g., regarding a kitten or a baby with big eyes). By contrast, *virtue* lacks such associations. Despite the fact that words like *virtue* are rated as high in (absolute) valence *offline*, their "ultralow" imageability may severely curtail access to emotional information during more immediate *online* lexical processing.

Discussion

The current study examined how the emotional valence of concrete and abstract words influenced their recognition in a lexical decision task. A large participant sample was recruited to investigate whether Emotion effects were modulated by individual variations in alexithymia. Importantly, we controlled the effects of word length, word frequency, arousal, familiarity, and AoA by matching these variables by item and/or including them as covariates in the analyses. In accord with previous findings, we found that emotional words (positive and negative) were recognized faster than neutral words. This Emotion effect significantly interacted with concreteness, and was significantly larger in concrete than in abstract words. This interaction was not driven by individual variations in alexithymia level, but was significantly modulated by word imageability.

Our findings do not lend support to the “representational substitution” hypothesis. Kousta et al.’s (2011) proposed that valence plays a more central role in representing abstract relative to concrete words. They suggested that abstract words are overall more emotionally valenced than concrete words, and that this higher level of valence leads to a residual processing advantage for abstract words when contextual availability and imageability are controlled. Building upon Barsalou and Wiemer-Hastings’ (2005) proposal for an introspective grounding for abstract concepts, they suggested that abstract words may be primarily represented in emotional experience to compensate for the lack of direct mappings to sensory experience. In other words, emotional experiences may be substituted for sensorimotor experiences in representing abstract words. This hypothesis predicts a larger Emotion effect in the lexical processing of abstract words. However, our data showed that the Emotion effect was more pronounced in the processing of concrete than abstract words, critically, when valence was matched between concrete and abstract words. Moreover, if abstract words are primarily represented in emotional experience, individuals with high levels of alexithymia (difficulties in identifying and describing emotions) should experience difficulty in processing such words. Our results suggested otherwise. Despite the presence of a wide range of alexithymia levels in our sample, responses to emotion versus neutral abstract words were not differentially modulated.

Our results provide stronger support for the “multimodal induction” hypothesis. Grounded cognition theories predict that emotional concepts (and concepts in general) are learned and mentally represented through multimodal (e.g., sensory, motor, and affective) experiencing of the physical and mental worlds (Barsalou, 2008). Partial activation of a conceptual system can lead to fuller activation of the conceptual representations in other domains (Niedenthal, 2007). In other words, emotional activation (e.g., joy) may benefit from activation of relevant sensorimotor information (e.g., seeing a smiling face). It predicts that the Emotion effect should be stronger in concrete than in abstract words, due to the former's higher levels of imageability (i.e., richer associations with sensorimotor experiences). Although concreteness and imageability are highly correlated, they capture, at least partially, different aspects of word semantics. Concreteness concerns the categorical ontological distinction between physical and conceptual entities and it is distributed bimodally; in contrast, the distribution of imageability is unimodal and it reflects the extent to which words are associated with sensorimotor information (Kousta et al., 2011). Our respective analyses on concrete and abstract words revealed differential relationships between Emotion and Imageability. In concrete words, Emotion and Imageability influenced word recognition of concrete words independently, which did not support the prediction that words with higher imageability would show a stronger Emotion effect. The Emotion effect in abstract words, in comparison, did interact with imageability – it was significant in abstract words having relatively higher levels of imageability (e.g., *cute*, *graceful*, *hell*, *disaster*), but not in low-imageability abstract words (e.g., *pure*, *exquisite*, *risk*, *atrocious*). This Emotion × Imageability interaction supports the "multimodal induction" hypothesis, suggesting that sensorimotor associations of abstract words (e.g., images of a kitten associated with the word *cute*) may act as catalysts for activating the emotional content of a word. Words having impoverished sensory associations (e.g., *virtue*) may score high in *off-line* valence ratings when enough time is given. Such words may struggle to activate emotional content during more immediate *online* lexical processing, resulting in non-significant valence effects in lexical decision times.

The discrepant relationships between Emotion and Imageability in concrete and abstract words imply that the activation of emotional content can benefit from activation of sensorimotor information, but only to a certain extent. In abstract words, where imageability is generally low, increases in sensorimotor associations can significantly promote the activation of emotional content which, in combination, facilitates word recognition. In concrete words, once a certain level of sensorimotor associations is reached, further increases in such associations cannot offer additional benefits to emotional activation (i.e., the facilitation effectively plateaus), at least not in the context of word recognition.

Such a non-linear relationship between Emotion and Imageability is evident in our materials. Emotion and Imageability were not correlated with each other in Concrete words [$r(133)=-.113$, $p=.193$], but were positively correlated in Abstract words [$r(133)=.506$, $p<.001$]. Importantly, we do not think that the differential correlations between Emotion and Imageability can be attributed to a sampling bias (i.e., we happened to select concrete words with independent valence and imageability values, and abstract words with correlated values). First, our materials comprised a substantial set of words (270 words) which was larger than comparable studies (240, 108, and 156 words in Kanske & Kotz (2007), Palazova et al. (2013), and Sheikh & Titone (2013), respectively) and were, consequently, more resilient to such biases. More importantly, we were able to replicate the correlations between valence and imageability based on a considerable database of local ratings (N=5553; Scott et al., *in prep*). We defined words with a concreteness rating (on a 7-point scale) of ≤3.5 as abstract (N=1587) and words with a concreteness rating of ≥4.5 as concrete

(N=2905). We found a significant, positive correlation between valence and imageability in abstract words [$r(1585)=.352$, $p<.001$]. The correlation in concrete words was negative and negligible, though it was nonetheless significant due to a very large N [$r(2903)=-.064$, $p=.001$]. These results confirm that the discrepant relationships between Emotion and Imageability in concrete and abstract words can be generalized to a much larger corpus of English words.

Conclusions

In sum, our study examined the effects of emotional valence and concreteness on word recognition in a lexical decision task. While emotional words generally enjoy an early processing advantage over neutral words, this emotion effect was significantly larger in concrete than in abstract words. This interaction could not be attributed to individual variations in alexithymia level, but instead was modulated by word imageability. The latter provides novel evidence for differential relationships between emotional content (valence) and sensorimotor information (imageability) in concrete versus abstract words. In contrast to concrete words, emotional facilitation of abstract words was dependent on their imageability. Overall, the pattern of effects did not support the “representational substitution” hypothesis as we demonstrated that emotional experience does not always contribute to the online lexical processing of abstract words. Instead, our findings supported the “multimodal induction” hypothesis with the proviso that, within the context of word recognition, emotional activation is not able to infinitely benefit from sensorimotor experiences.

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Appendix A: Word Stimuli

	Abstract			Concrete	
Negative	**Neutral**	**Positive**	**Negative**	**Neutral**	**Positive**
woe	wee	vow	axe	keg	hug
sin	bid	wit	rat	fur	spa
bad	add	win	cut	cup	bed
liar	gist	cute	wasp	mast	wink
fury	tame	cosy	stab	oval	sing
evil	mild	bold	riot	horn	toys
hell	mood	luck	jail	jury	silk
fear	duty	pure	bomb	path	gold
risk	stay	wish	fire	list	cash
manic	aloof	bliss	vomit	clown	panda
curse	overt	haven	shark	alley	bunny
agony	irony	mercy	snake	spray	daisy
cruel	array	bonus	flood	arrow	pearl
chaos	drift	glory	storm	cliff	movie
crazy	limit	brave	crash	canal	ocean
wrong	apply	trust	blood	field	smile
malice	frugal	valour	knifed	girdle	gadget
betray	satire	nimble	dagger	crater	kitten
punish	oblige	vigour	bullet	sponge	jewels
doomed	rating	admire	scream	statue	parade
scared	custom	worthy	poison	basket	trophy
terror	casual	virtue	crying	petrol	cinema
fierce	subtle	honest	weapon	liquid	flower
suffer	aspect	belief	murder	mirror	dinner
afraid	affect	create	prison	leaves	castle
danger	method	useful	battle	winter	garden
oppress	thrifty	refresh	tsunami	archery	snowman
deceive	prolong	agility	tornado	goggles	glitter
treason	preface	playful	grenade	glacier	lottery
anguish	persist	sublime	shotgun	herring	bouquet
furious	gradual	gallant	hostage	luggage	blossom
hostile	convert	sincere	robbery	stadium	balloon
painful	passive	liberty	missile	leaflet	rainbow
anxiety	partial	courage	surgery	leather	wedding
insanity	subtract	graceful	scorpion	tapestry	ladybird
paranoid	classify	devotion	assassin	mechanic	comedian
sinister	perceive	abundant	massacre	triangle	treasure
shocking	reserved	fabulous	attacker	calendar	birthday
jealousy	abstract	inspired	shooting	corridor	princess
disaster	describe	advanced	criminal	document	festival
atrocious	deduction	dignified	tarantula	appliance	astronaut
psychotic	mythology	exquisite	hurricane	wrestling	limousine
obscenity	deviation	gratitude	terrorist	container	butterfly
irritating	conceptual	prosperous	earthquake	technician	graduation
catastrophe	indifferent	sensational	executioner	thermometer	millionaire

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Table 1

Means (with *SDs*) of Target Word Specifications across Conditions

	Abstract Negative	Abstract Neutral	Abstract Positive	Concrete Negative	Concrete Neutral	Concrete Positive
N	45	45	45	45	45	45
Valence	2.17 (.56)	5.11 (.53)	7.35 (.57)	2.50 (.79)	5.08 (.47)	7.00 (.55)
|Valence|	3.83 (.56)	1.47 (.26)	3.35 (.57)	3.50 (.79)	1.37 (.30)	3.00 (.55)
Concreteness	2.84 (.36)	2.83 (.46)	2.80 (.40)	5.97 (.58)	6.04 (.40)	6.03 (.51)
Frequency	23.6 (36.0)	23.3 (29.1)	22.7 (32.0)	22.6 (36.2)	23.5 (36.2)	22.2 (32.9)
Log Frequency	1.00 (.58)	1.05 (.56)	1.01 (.55)	0.94 (.63)	0.99 (.58)	0.93 (.63)
Length	6.22 (1.88)	6.22 (1.88)	6.22 (1.88)	6.22 (1.88)	6.22 (1.88)	6.22 (1.88)
Arousal	5.59 (.60)	3.95 (.65)	5.81 (.76)	5.59 (.80)	3.91 (.60)	5.85 (.67)
Familiarity	5.27 (.69)	4.95 (.81)	5.19 (.85)	5.24 (.59)	5.31 (.85)	5.76 (.58)
AoA	4.36 (1.21)	5.02 (1.09)	4.55 (1.17)	3.85 (1.07)	3.69 (1.15)	2.97 (1.06)
Imageability	3.81 (.75)	2.87 (.61)	3.41 (.64)	6.09 (.53)	6.11 (.45)	6.32 (.47)

Note: Units of measures are as follows: Valence on a scale from 1 (very negative) to 5 (neutral) to 9 (very positive); |Valence|=abs(valence-5)+1, ranging from 1 (neutral) to 5 (highly valenced); Concreteness on a scale from 1 (very abstract) to 7 (very concrete); Frequency in occurrences per million; Length in number of letters; Arousal on a scale from 1 (very unarousing) to 9 (very arousing); Familiarity on a scale from 1 (very unfamiliar) to 7 (very familiar); AoA (age of acquisition) on a scale from 1 to 7 (ages 0-2, 3-4, 5-6, 7-8, 9-10, 11-12, and 13+ years, respectively); and Imageability on a scale from 1 (very unimageable) to 7 (very imageable).

Table 2

Mean RT (in ms) and %Error across Experimental Conditions

	Abstract			Concrete		
	Negative	**Neutral**	**Positive**	**Negative**	**Neutral**	**Positive**
RT	571 (69)	596 (76)	577 (72)	562 (66)	580 (71)	552 (66)
%Error	2.3 (2.9)	5.3 (4.0)	3.5 (3.2)	1.7 (2.7)	4.6 (3.7)	1.4 (2.0)

Note: Standard deviations (*SD*s) are listed in parentheses.

Table 3

Emotion × Concreteness: LMM Results

Predictors	*b*	*SE*	*p*	VIF
Log Frequency	-11.74	0.82	<.001	1.14
Arousal	-2.67	0.74	<.001	1.46
Familiarity	-13.41	0.83	<.001	1.30
AoA	9.25	1.13	<.001	1.35
Emotion	-6.24	0.86	<.001	1.48
Concreteness	-2.86	0.71	<.001	1.17
Emotion × Concreteness	-1.76	0.62	.005	1.02

Note: AoA=age of acquisition; Emotion (i.e., absolute valence); and VIF=variance inflation factor.

Table 4

Emotion × Concreteness × Alexithymia: Linear Regression Model Results

Predictors	***b***	***SE***	***p***	**VIF**
Log Frequency	-11.57	0.78	<.001	1.54
Arousal	-2.57	0.89	.004	2.00
Familiarity	-13.75	0.96	<.001	2.32
AoA	9.17	1.04	<.001	2.68
Emotion	-6.24	0.91	<.001	2.05
Concreteness	-2.78	0.78	<.001	1.54
Alexithymia	3.55	0.64	<.001	1.03
Emotion × Concreteness	-1.71	0.68	.012	1.06
Emotion × Alexithymia	0.57	0.65	.378	1.03
Concreteness × Alexithymia	-0.36	0.64	.580	1.03
Emotion × Concreteness × Alexithymia	-0.22	0.66	.740	1.04

Note: AoA=age of acquisition; Emotion (i.e., absolute valence); Alexithymia (i.e., TAS score); and VIF=variance inflation factor.

Table 5

Emotion × Concreteness × Imageability: Reduced LMM Results

Predictors	***b***	**SE**	***p***	**VIF**
Log Frequency	-11.46	0.83	<.001	1.17
Arousal	-1.93	0.75	.011	1.49
Familiarity	-14.02	0.84	<.001	1.32
AoA	8.30	1.16	<.001	1.42
Emotion	-12.07	1.21	<.001	2.98
Imageability	-4.60	0.76	<.001	1.27
Emotion × Imageability	-1.52	0.63	.017	1.13
Concreteness × Imageability	-2.93	1.05	.006	1.08
Emotion × Concreteness × Imageability	6.15	0.97	<.001	2.54

Note: AoA=age of acquisition; Emotion (i.e., absolute valence); and VIF=variance inflation factor.

Table 6

Emotion × Imageability: LMMs on Abstract and Concrete Words

	Abstract				Concrete			
	b	*SE*	*p*	VIF	*b*	*SE*	*p*	VIF
Log Frequency	-12.41	1.11	<.001	1.37	-11.02	1.01	<.001	1.18
Arousal	-1.54	1.05	.142	1.48	-3.38	1.06	.002	1.65
Familiarity	-16.64	1.21	<.001	1.46	-10.47	1.07	<.001	1.45
AoA	5.56	1.63	<.001	1.64	8.91	1.10	<.001	1.55
Emotion	-6.25	1.25	<.001	1.62	-6.73	1.13	<.001	1.70
Imageability	0.10	1.03	.921	1.48	-1.79	0.83	.033	1.25
Emotion × Imageability	-4.59	0.78	<.001	1.13	0.82	0.79	.302	1.07

Note: AoA=Age of Acquisition; Emotion (i.e., absolute valence); and VIF=Variance Inflation Factor.

Figure 1

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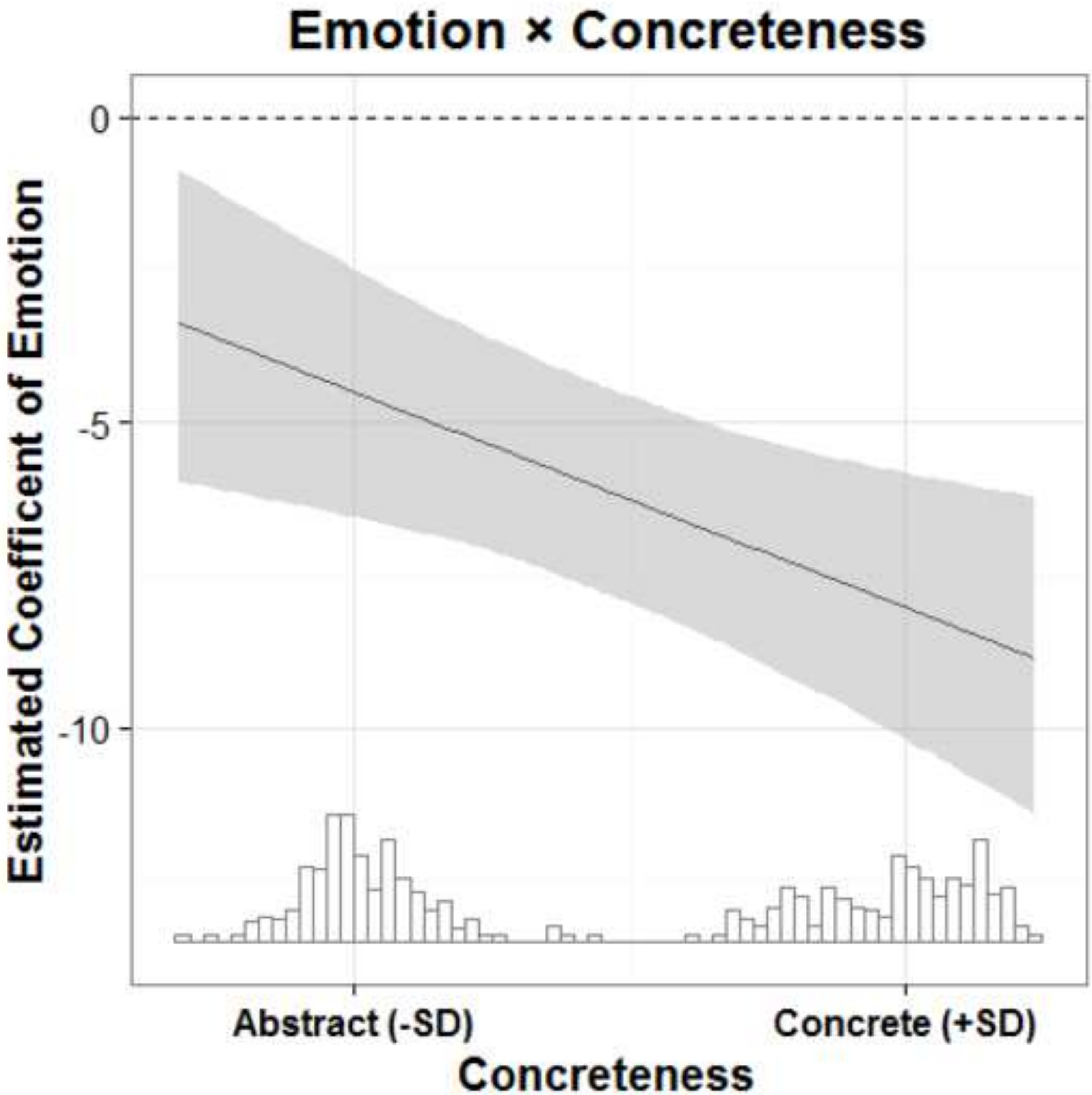

Figure 2

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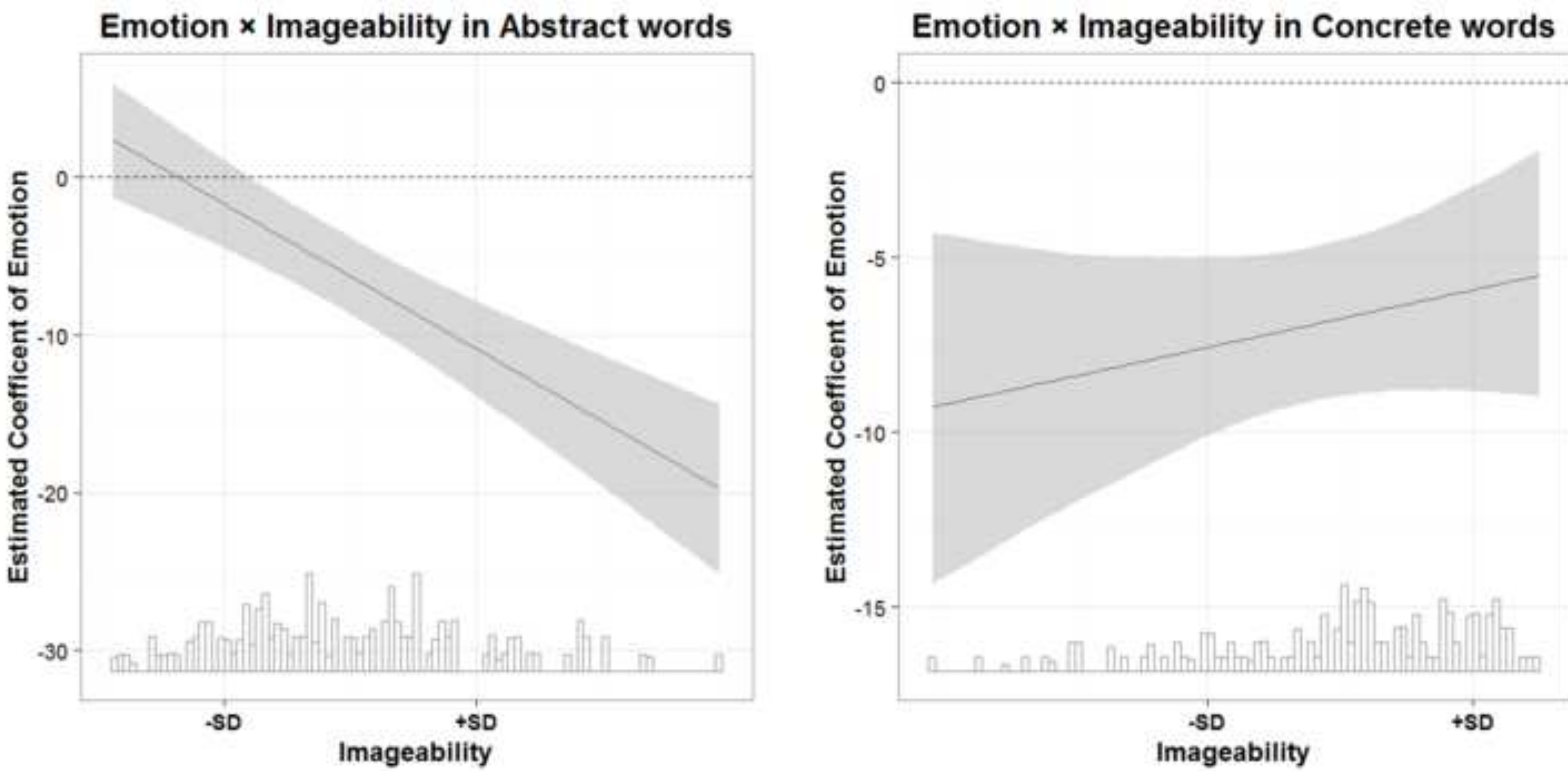

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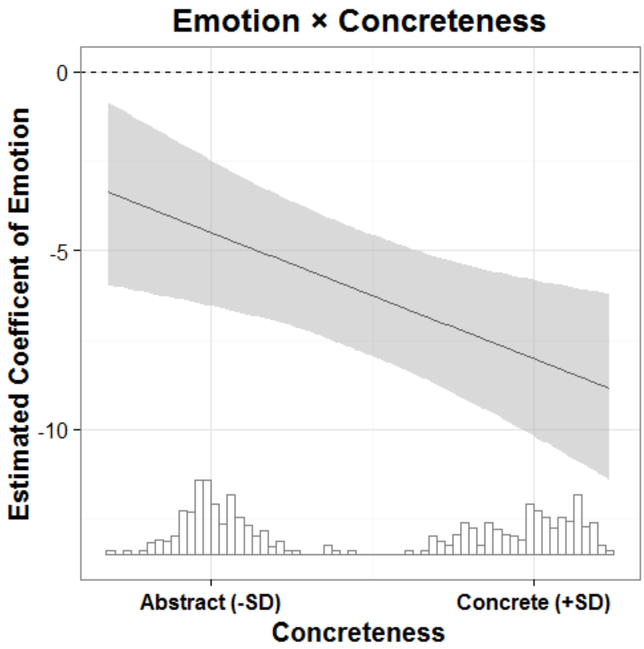
Figure 1

Estimated Coefficient of Emotion across Concreteness

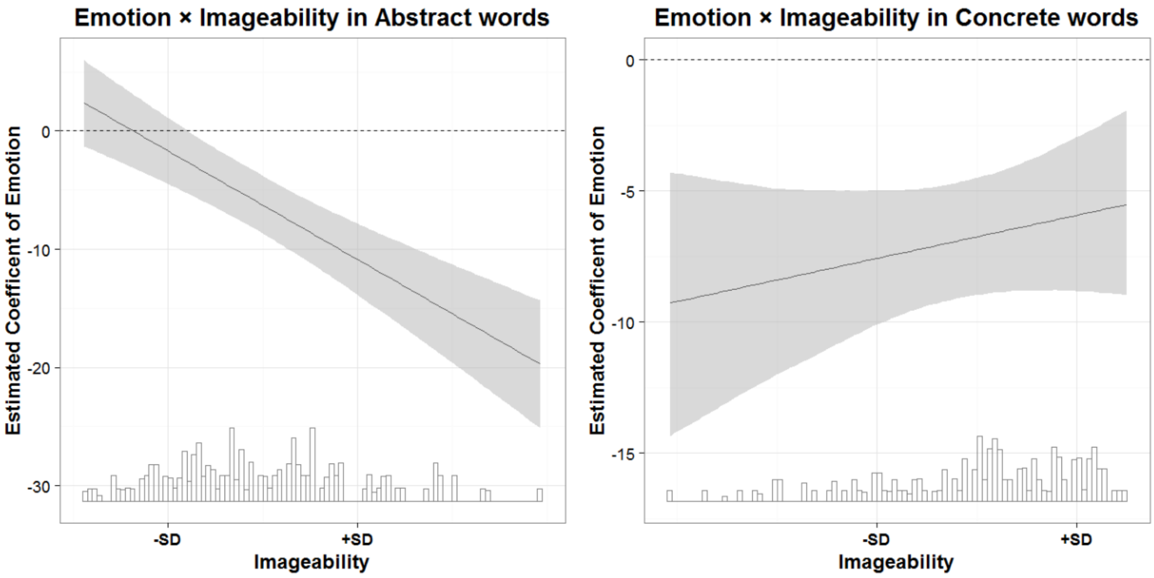


Note: The solid line represents the estimated coefficient of emotion across levels of concreteness. The grey areas indicate the 95% confidence interval around the estimated coefficient. The histogram at the bottom of the figure illustrates the distribution of concreteness levels of stimulus words.

Figure 2

Estimated Coefficient of Emotion across Imageability levels

in Abstract words (left) and Concrete words (right)



Note: The solid lines represent the estimated coefficients of emotion across levels of imageability in Abstract words (left panel) and Concrete words (right panel). The grey areas indicate the 95% confidence intervals around the estimated coefficients. The histogram at the bottom of each panel illustrates the distribution of concreteness levels of stimulus words.